Flow-Vegetation Interactions at Vegetated Riverbanks

Experimental Analysis of Flume Data and Measurements in the River Dinkel

Riverbank vegetation has numerous positive effects on water quality, biodiversity and riverbank stability. However, it could also obstruct natural water flow and contribute to flooding. To make informed decisions on the management of riverbank vegetation in natural streams, it is crucial to understand the complex flow-vegetation interaction. Previous research into flow-vegetation interactions has relied predominatly on simplified laboratory experiments, which may not fully represent real-world conditions. Therefore, further investigation is needed to accurately study and compare the flow dynamics within and around natural riverbank vegetation to inform better management practices and investigate the representativeness of the idealised derived formulae from flume studies when applied under real-world conditions.

First, the study examined flow through two submerged macrophyte species, *Callitriche platycarpa* (dense) and *Groenlandia densa* (sparse), in different configurations within a flume. The findings of this flume study emphasise the importance of considering the interaction of different vegetation patches when studying the flow-vegetation dynamics in natural aquatic habitats, as the spatial configuration of two vegetation patches affects the wake development and the recovery downstream of a vegetation patch. Furthermore, the flume study underlines that two vegetation patches close to each other do not necessarily mean they act hydrodynamically as one vegetation patch.

Next, flow-vegetation interactions under natural conditions were investigated along the River Dinkel's vegetated banks and the applicability of formulae from flume experiments was assessed. Flow measurements were collected within and around patches of two macrophyte species: *Carex sylvatica* and *Sparganium emersum*. The density of riverbank vegetation affects flow velocity, turbulence within patches, and river cross-sections. Large Scale Kelvin-Helmholtz vortices develop at the interface of the slow flow within vegetation and faster open-channel flow. These vortices contribute significantly to transverse shear stress.

Idealised models were tested against field data for transverse momentum exchange and lateral streamwise flow velocity profiles. The vortex-based model of White and Nepf (2008) performs well but overestimates lateral momentum exchange near inflection points and within vegetation patches. The hybrid eddy viscosity model by Truong and Uijttewaal (2019) accurately captures transverse momentum exchange. The exponential-based model by Liu et al. (2022) performs adequately when utilising measured mixing layer widths but performs adequately when using empirical estimates.

A combination of the exponential-based and hybrid eddy viscosity models shows potential for understanding flow-vegetation interactions without direct measurements. However, the performance of empirical relationships in both models underscores the need for better empirical relationships for mixing layer widths in natural conditions.

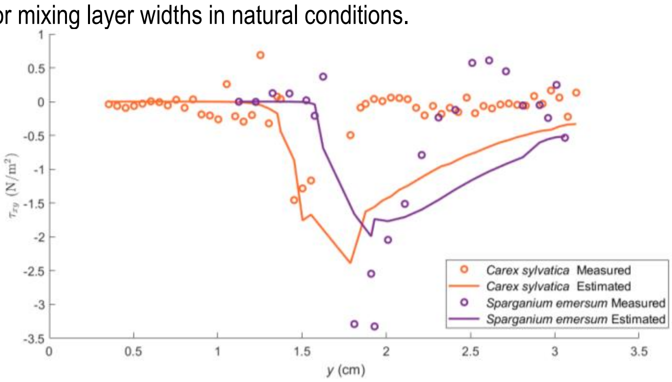

Figure 1: A comparison between the measured and the predicted lateral shear stress of the momentum exchange by the Hybrid model of Truong and Uijttewaal (2019) using the predicted flow velocities according to the exponential-based model of Liu et al. (2022) with the empirical estimates for the inner and outer mixing layer widths.

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Truong, S. H., & Uijttewaal, W. S. J. (2019). Transverse Momentum Exchange Induced by Large Coherent Structures in a Vegetated Compound Channel. Water Resources Research, 55(1), 589–612. https://doi.org/10.1029/2018WR023273
White, B. L., & Nepf, H. M. (2008). A vortex-based model of velocity and shear stress in a partially vegetated shallow channel. Water Resources Research, 44(1), 1412. https://doi.org/10.1029/2006WR005651

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